

Vadose Zone Weathering Rates Inferred from U-Series Disequilibrium

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The U-series isotope system can be used to quantify reaction rates in aquifers and thick vadose zone environments. The approach is based on the α -recoil of ^{234}Th atoms across grain boundaries, which enriches the pore fluid in ^{234}U . Dissolution of the solid phase releases mainly ^{238}U to the pore fluid, so that the $^{234}\text{U}/^{238}\text{U}$ activity ratio of the pore fluid is a measure of the local ratio of the dissolution U flux to the α -recoil flux. The interpretation of U-series disequilibrium in weathering environments depends on the α -recoil flux, which is highly dependent on both the distribution of U and the grain size distribution of the soil. The recoil length of the ^{234}Th atom in a silicate is approximately 700 Å, therefore the fine-grained material, with a greater surface area to volume ratio, contributes a significant amount of the ^{234}U to the porewater. As a result, estimates of the recoil flux based on the mean grain size may under predict the supply of ^{234}U by over an order of magnitude. In order to quantify the reaction rate, this recoil flux must be accurately measured by consideration of the recoil contribution of the fine-grained material, despite the fact that it may only comprise a small fraction of the total mass of the sediment. U concentrations and high precision isotope measurements ($^{234}\text{U}/^{238}\text{U}$) of pore fluids, mineral separates, and grain size intervals are used to constrain reaction rates for a 70 m vadose zone core from eastern Washington State. The pore water $^{234}\text{U}/^{238}\text{U}$ activity ratios range from 1.04 to 1.20 in the pore fluids, and from 0.94 to 1.0 in the various size fractions. Data from the solid phases is used to construct a predictive model for α -recoil flux in heterogeneous soil. The calculated recoil loss, which considers each grain size interval, is up to 7 times greater than for a geometric prediction based on the mean grain size. The measured $^{234}\text{U}/^{238}\text{U}$ ratios for the vadose zone, in conjunction with the estimates for the α -recoil flux, yield weathering rates of approximately $10^{-6.4} \text{ yr}^{-1}$, which agree with estimates derived from measurements in granitic soils that are based on mineral abundances and soil age. The data suggest that recoil loss from the fine-grained size fractions in a heterogeneous soil can have a significant impact on the interpretation of U isotopic data.